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ROGER DUHAMEL, F.R.S.C.
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Published under Authority

of

HON. H. J. ROBICHAUD, M.P.

Minister of Fisheries

The Effect of a Marine Seismic Exploration on Fish Populations in British Columbia Coastal Waters

by

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and

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Abstract

The Shell Oil Company of Canada conducted a marine seismic survey off the west coast of British Columbia during the summer months of 1963. Because of the potential damage to local fish populations through exposure to high velocity explosives, the Department of Fisheries of Canada conducted a program of supervision and control on the Company's field operations. The Company agreed that the on site departmental biologist would have full authority to suspend or terminate any shooting procedures judged to be detrimental to fish populations.

Observations throughout the survey revealed that 419 (4.3 percent) of a total of 9,638 shot points exhibited a total surface mortality of 59,277+ fish. Herring and rockfish represented 72.2 and 23.8 percent of the total kill respectively with the remaining four percent consisting of 189+ adult salmon, 467+ juvenile salmon and 1,732+ miscellaneous fishes. Large charges (50–300 pounds) of nitrone S.M., typical of refraction shooting, killed more fish more frequently than light charges (5–25 pounds) typical of reflection shooting. An increase in detonation depth increased the area of potential fish kill. In shallow water (less than 34 fathoms) the horizontal lethal range of a seismic explosion is greater than in deep water (greater than 34 fathoms). Surface observations of fish mortality were not a reliable measure of charge lethality since they do not account for subsurface mortality. Under existing operational conditions only the vertical scanner on the fish detection unit was found useful in detecting the presence of fishes. In view of the area covered and number of shot points subjected to high velocity explosives, the resulting fish mortality was considered relatively light.

Introduction

Marine seismic exploration for new petroleum resources has been accelerated on a world-wide basis since the end of World War II. The increasing energy

demands of industry and population growth are stimulating nations to look beneath the seas for new oil reserves. In this search seismic* techniques are used which reveal subterranean structure through interpretation of shock waves caused by controlled explosive detonations. Explorations were initially restricted to shallow water areas bordering continental coastlines. However, recent advances in drilling procedures have permitted oil companies to feasibly extend their continental shelf explorations into waters deeper than 100 fathoms. By 1961 such advances enabled marine seismic explorations to be carried out in shelf regions bordering the Persian Gulf, Sea of Japan, Gulf of Paria, Venezuela, North Sea, Holland, Nigeria, Africa and British Columbia, Canada (Rulifson and Schoning, 1963). Extensive surveys are presently underway along the coastlines of the United States and Canada. This report will describe one of the most recent surveys off the west coast of British Columbia and the observed effects of conventional seismic methods on the local fish populations.

Shock waves produced by detonation of high velocity explosives provide the best information on substrata geology. Experimental evidence (Hubbs, Schultz and Wisner, 1960) has shown high velocity explosives to be capable of killing substantial numbers and many kinds of marine fauna. Hubbs and Rechnitzer (1952) found that low velocity black powder explosives up to 90 pounds proved to be relatively innocuous to fish populations. The former situation, if not carefully monitored, could result in a serious loss of commercially valuable fish and invite severe criticism from the fishing industry and general public.

During 1961 Shell Oil Company of Canada secured petroleum exploration rights on 11.9 million acres of offshore water along the coast of British Columbia, Canada. The area (see Figure 1) extends from Barkley Sound off the southwest coast of Vancouver Island northerly to north central Hecate Strait. In late 1962 the Company contacted the Department of Fisheries of Canada and briefly outlined their proposed program of exploration which would utilize the gas-exploder and high velocity explosive techniques. The Company wished to discuss any recommendations or objections the Department might have concerning the proposed program.

In the course of subsequent technical meetings the Company described in detail the seismic techniques to be employed and presented a plan of operation which included the timing and specific locations of the survey lines.

In recognition of the potential damage inherent in an operation of this nature and magnitude, the Department concurrently presented a draft of conditions which would provide adequate protection to the fishery resource in an area frequented by salmon, herring, halibut and crab fisheries.

Responsibility for protection of the fishery is provided for in the 1932 Canada Fisheries Act.

*Seismic in this report will mean artificially created shock waves caused by controlled explosives as opposed to naturally created shock waves caused by earthquakes, etc.

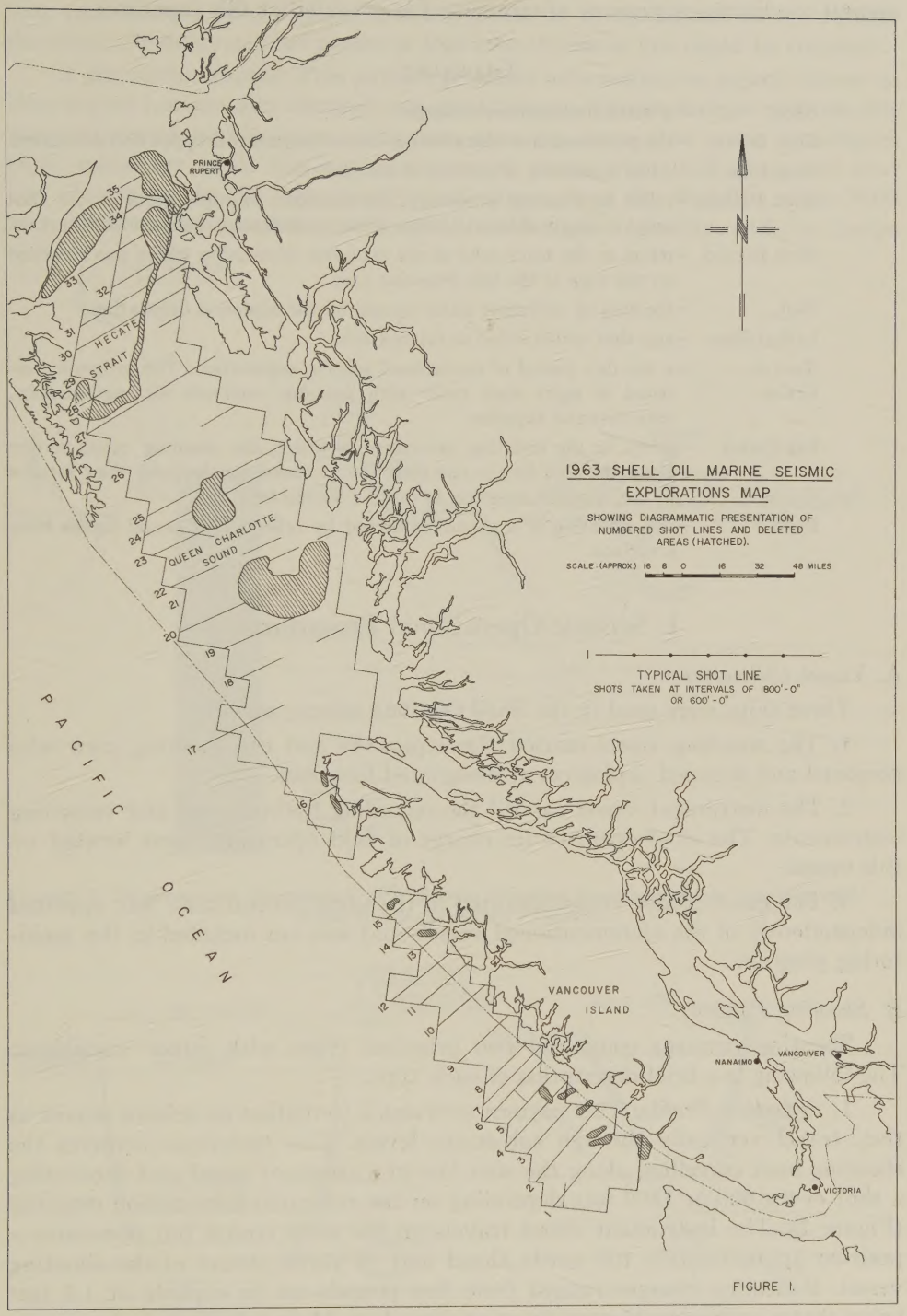

FIGURE 1.

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To facilitate a clearer understanding of the seismic procedures and departmental conditions, a glossary of terms used is provided at this juncture:

GLOSSARY

Shot	—a detonated explosive charge.
Shot Point	—the point location where the explosive charge was dropped and detonated.
Shot Line	—a line consisting of a series of shot points.
Shot Pattern	—refers to shooting procedure; for example: multiple shots at one shot point or single shots at a series of shot points at predetermined intervals.
Shot Record	—refers to the trace echo of the explosive detonation which was recorded on the tape of the fish detection unit.
Boil	—the area of turbulent water caused by the explosive detonation.
Lethal Shot	—any shot which killed or injured fish.
Tour or Cruise	—a ten day period of operational seismic exploration. The program consisted of eight such tours with five-day intervals for maintenance, crew rest and supplies.
Leg (pass)	—refers to the shooting procedure in which the shooting vessel moves along the shot line in one direction to make one leg and then returns in the opposite direction to make a second leg.
Echo	—the repeating of a sound, produced by reflection of sound waves from a surface.

I. Seismic Operational Procedures

A. *Vessel Utilization:*

Three ships were used in the Shell Oil 1963 seismic survey.

1. The shooting vessel carried the explosives and the shooting crew who prepared and dropped explosives at designated locations.

2. The instrument vessel carried the recording hydrophones and recording instruments. The chief operator (in charge of field operations) was located on this vessel.

3. The gas-exploder vessel operated in the same general area but operated independently of the aforementioned vessels and was not included in the monitoring program.

B. *Shooting Patterns*

Shooting patterns consist of two principal types with minor variations. The following is a brief description of each type.

1. *Reflection Profile:* This pattern provides information on seismic waves as they travel vertically through sub-strata levels. This technique involves the shooting boat travelling along the shot line at a constant speed and detonating a shot every 600 or 1800 feet depending on the reflection information required (Figure 2). The instrument vessel travels on the same course but maintains a position approximately 100 yards ahead and 30 yards abeam of the shooting vessel. Reflection charges ranged from five pounds set to explode at 1.5 feet below water surface to 25 pounds set at three feet. Most reflection shot patterns involved up to 200 shots detonated at intervals of one to three minutes, depend-

ing on the distance between shot points (600 or 1800 feet). At the end of the first pass along a shot line the pattern would be re-established in the reverse direction. As many as four passes or legs over the same line could be required.

2. *Refraction Profile:* This pattern provides information on seismic waves as they travel horizontally through sub-strata levels. This technique involves the shooting vessel making repeated passes over the same shot point in a figure eight maneuver while the instrument vessel moves away and along the shot line (Figure 3). As the instrument vessel moves along the shot line every 3600 feet, the shooting vessel is maneuvered into shot point position and the charge

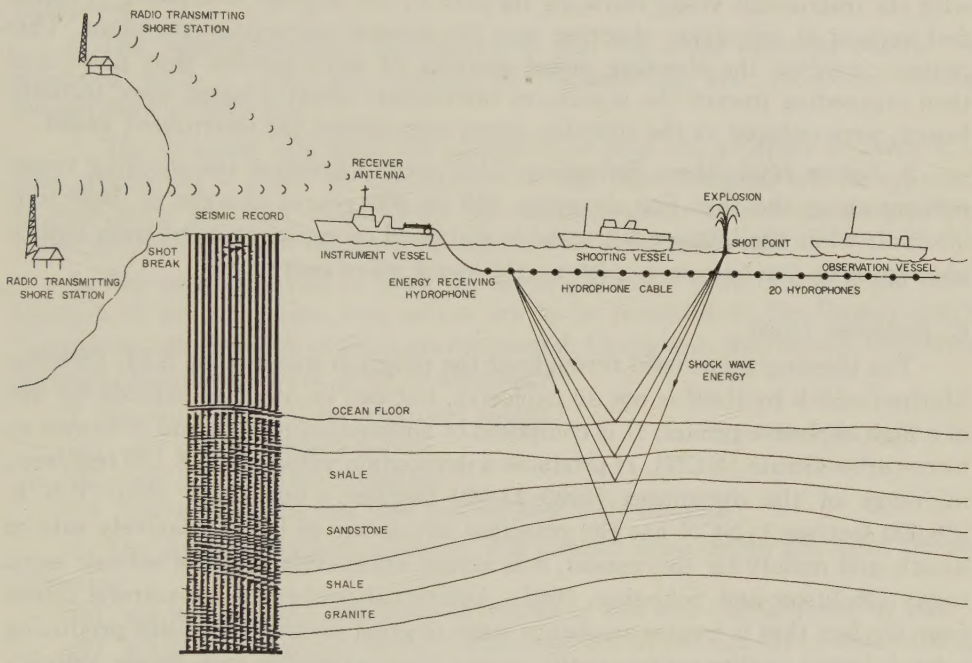

FIGURE 2. *Diagrammatic Presentation of Reflection Shooting Procedure, Vessel Location and Type of Seismic Record Produced.*

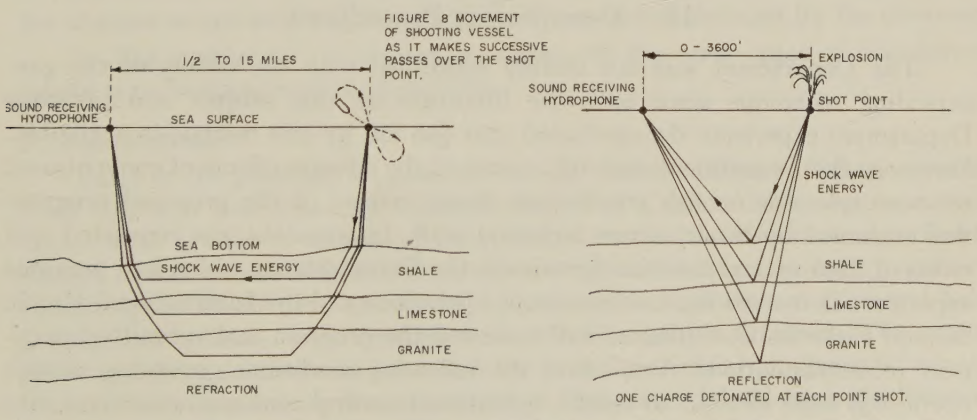

FIGURE 3. *Diagrammatic Presentation of Reflection and Refraction Shooting Methods.*

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is dropped into the water. The detonation occurs after the all-clear signal is given by the shooting vessel and is triggered by a remote control device aboard the instrument vessel. The size and depth setting of the charges used ranged from 10 pounds set to explode three feet from the surface to 300 pounds set at 40 feet. Charge sizes are increased as the distance between the instrument vessel and the shot point increases. Between shots there is usually a six minute time interval before the two vessels are in position for the next shot. Usually 10–20 charges are exploded on a shot point whereupon the shooting vessel proceeds to a shot point at the opposite end of the shot line and the procedure is repeated with the instrument vessel retracing its path to the original shot point. A modified version of refraction shooting was the reverse refraction procedure. This pattern involves the shooting vessel starting at some distant shot point and then proceeding toward the stationary instrument vessel. Charge sizes, initially heavy, were reduced as the shooting vessel approached the instrument vessel.

3. *Bottom Hydrophone Refraction:* This pattern involves the shooting vessel moving along the shot line dropping 100 to 300 pound charges at 3600 foot intervals while the instrument vessel is stationed on one shot point with hydrophones set on the bottom to pick up the shock wave energy.

C. *Explosive Used:*

The blasting agent used throughout the program was nitrone S.M. (Seismic Marine) which by itself is not an explosive, but can be made to explode by use of a high explosive primer. It is composed of ammonium nitrate and is known as nitro-carbo-nitrate (NCN). It produces a detonation velocity of 15,100 feet/sec., midrange of the dynamites (4000–23,000 feet/sec.) but lower than T.N.T. (20,000 feet/sec.). NCN has the principal advantage of being relatively safe to handle and mainly for this reason, it is almost exclusively used for seismic work today (Rulifson and Schoning, 1963). Additional preference for nitrone comes from the fact that it creates an abrupt wave of great pressure intensity producing a much better quality seismographic record than is possible with slower velocity explosives such as black powder (Hubbs and Rechnitzer, 1960).

II. Department Procedures

The Department was not unduly concerned with the effects of the gas-exploding technique since both the literature on this subject and previous Department experience demonstrated that fish kill by this method is negligible. However, the Department was fully aware of the adverse effects of conventional seismic explosions on fish populations. Every aspect of the proposed program was examined by headquarters technical staff. Information was requested and received from several fisheries agencies in the United States, which had previous experience in monitoring marine seismic operations and the International Pacific Salmon Fisheries Commission staff reviewed the program and submitted pertinent recommendations. As a result the following conditions governing seismic operations were drafted to ensure operational control and minimize mortality to the fishery.

A. *Conditions Governing Seismic Operations:*

1. A Department of Fisheries biologist observer will be carried aboard the shooting vessel. This shooting vessel will be equipped with a fish scanning device for locating fish and recording bottom depth.

2. An observation vessel will be provided by the Company for the Department. An assistant observer will be carried aboard the observation vessel for the purpose of observing and numerically recording fish mortality.

3. It is understood that both the observer and his assistant will be hired by the Department and be responsible to the Department and paid for by the Company.

4. The vessels carrying the observers and the chief operator should be equipped with a radio set capable of transmitting and receiving on the Department's frequency.

5. The observer will have full authority to stop the program or delay it if time is required to check for the presence of fish. The Company will be expected to miss shots or avoid areas where fish concentrations have been observed or where in the opinion of the observer damage to fish would result.

6. The exact location of both the survey lines for reflection and the exact location of the refraction shot points are to be provided to the Department's Vancouver office as soon as plans are completed. Changes in plan should be cleared through this office a week prior to shooting.

7. Shooting will not be approved within:

(*a*) one mile of vessels fishing.

(*b*) one mile of river estuaries.

(*c*) one mile of the low tide line on any body of land.

8. The sizes of charges approved will depend upon depth governed by the following:

(*a*) up to 5 pounds of nitrone in depths of 200 feet (34 fathoms) or less.

(*b*) up to 25 pounds of nitrone in depths of 200 to 300 feet (34 to 50 fathoms).

(*c*) up to 300 pounds of nitrone in depths in excess of 300 feet (50 fathoms).

Each shot of over 25 pounds in waters of less than 50 fathoms in depth will require special consideration before approval can be granted. The approval to fire charges of any size will be subject to on-site restrictions set by the observer.

9. The portion of the survey in waters off the west coast of Vancouver Island is to be completed by June 15th.

B. *Deleted Areas:*

Early in the planning stage of the survey, Fishery Officers, Fisheries Patrol Boat Captains and Fisheries Research Board of Canada Scientists were contacted with a view to obtaining information on the distribution and probable density of fish populations in the survey area. Based on the information gained, specific areas which were known to support substantial stocks of ground fish, herring and salmon, were deleted from the Company's program. The major portion of these deleted areas were located in Hecate Strait and Queen Charlotte Sound. Small areas along the west coast of Vancouver Island were also deleted from the Company's program (Figure 1).

C. *Field Representatives:*

In accordance with the aforementioned agreement the Department contracted the services of a professional fisheries biologist who, as the departmental observer, was assigned the following responsibilities under the direction of headquarters technical personnel.

1. Supervise and regulate shooting procedures with the objective of avoiding excessive fish kill. It was considered impossible to avoid killing small numbers of fish without seriously handicapping the purpose of the exploration.

2. Search by means of a suitable fish detection device for presence of fish in the vicinity of the proposed shot points.

3. Record observations and prepare a final report on the effects of the seismic program on local fish populations.

4. Co-ordinate observations and recording procedures.

The assistant observer recorded species and estimated the number of dead or injured fish at each shot location.

As outlined in the original agreement pre-planned maps were submitted to the Department by the Company well in advance of the commencement date. Close liaison was maintained between the Department field personnel and headquarters staff. Requests for major program changes were referred to the Area Director of Fisheries for clearance. Minor changes requested by the Company were cleared through the on-site fisheries observer while on tour.

D. *Fish Detection Unit:*

Considerable effort was spent selecting the type of fish detection unit that would provide the best possible results. After corresponding with several American agencies which had experience with such units, a Simrad White Line Recorder was selected. However, this choice was abandoned when it was apparent that this machine was not adaptable to the vessel that the Company had chartered. A comparable alternative was found in the Kelvin Hughes, Ceres Fish Finder, Model MS 29 F. Features of this machine include:

1. Uses either moist or dry recording paper.

2. A whiteline amplifier for distinguishing bottom fish from the bottom.

3. A flashing neon light on the pen arm for initial target and depth indication.

4. A loudspeaker (or headphones) for audible signals.

5. A hand-operated hydraulic training unit which permitted scanning 135° to port and starboard.

6. Time indicator marker which records at one-minute intervals on the recording paper.

7. Four echo ranges selected by a simple gear adjustment.

8. Horizontal detection up to 960 yards and vertical depth detection down to 480 fathoms.

9. One recorder provided the comprehensive search facilities detailed above, namely long horizontal sound beam or short range searching (intermediate angle sound beam) and echo sounding (vertical sound beam) (Figure 4).

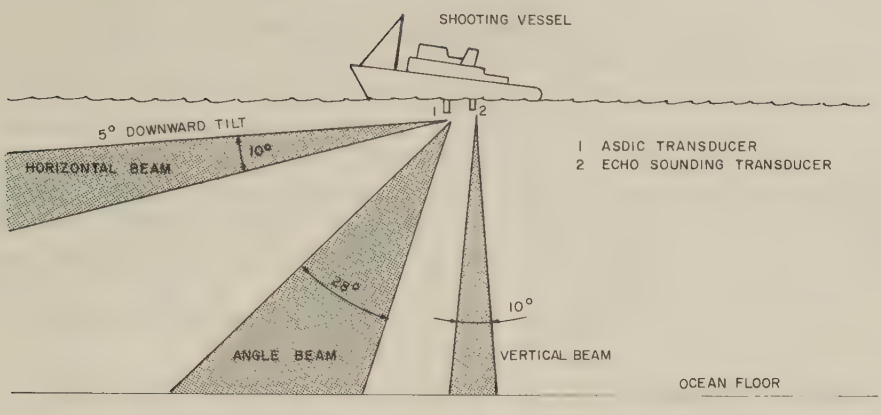

FIGURE 4. *Diagram Showing Area Coverage by Fish Scanner Sound Beams.*

E. *Field Procedures:*

1. *Radio Contact:* Direct radio contact between the assistant observer and the biologist observer was maintained throughout all shooting patterns. On occasions when the fish detection unit did not record the presence of fish, assessment of potential mortality and resultant decisions in respect to shot pattern suspension were facilitated by immediate communication between the observers.

2. *Refraction:* Before commencing a refraction series the shooting boat passed over the shot point and the area was searched with the Ceres Recorder for evidence of fish. If fish were detected the chief operator aboard the instrument vessel was requested to move to a new shot point location or to be prepared to do so if indication of sizeable fish kills were observed. If, however, there were no indications of substantial numbers of fish the shot pattern commenced with small charges and increased to larger charges as the instrument vessel moved away from the shot point. After the first shot of a refraction pattern the fish detector unit was alternately switched from its horizontal to vertical components to continually search for indications of fish. The assistant observer on board the observation vessel examined the boil for a period of 4–6 minutes and then moved out of the area when the shooting vessel returned for the next shot. At some refraction shot points where the chief operator wished to commence shooting with heavy charges and where there were indications of fish, test charges were detonated. If no fish were observed on the surface following the test shot, the shot pattern was permitted to begin.

3. *Reflection Procedure:* During reflection shooting the vertical component of the fish detection unit was kept in continuous operation in order to record water depth, shot record and fish presence. Since the speed of the shooting vessel was relatively constant, fish indications could be more accurately located in terms of their horizontal and vertical distances from the shot point. The observation vessel during reflection shooting was usually located from two to four hundred yards behind the shooting vessel.

4. *Diving Assessment Program:* During the last cruise, at the Department's request, the Company allotted one day for an assessment of the effects of under-

water explosives on fish populations. Two professional scuba divers and a departmental diver made pre-explosion and post-explosion observations of fish at shot points. Anchored marker buoys were set in shallow water areas inhabited by fish as indicated on the fish detection unit. Prior to shooting, the divers, using pre-measured ropes tied to the anchor, searched for and recorded the number of fish in 25, 50, 75 and 100 foot radius circles. After the shot was detonated beside the marker buoy, the divers repeated the search pattern and recorded the number, location and condition of fish present. Through comparison of the pre-examination and post-examination periods, the data obtained provided additional information concerning:

(*a*) The extent of the horizontal radial effect of underwater explosions in relatively shallow water (10–12 fathoms).

(*b*) The difference in numbers between observed surface fish mortality and total mortality.

(*c*) The effect of explosions on fish with and without gas bladders.

5. *Species Identification:* In order to determine what fish species were affected by the seismic explosives, random fish samples were taken and preserved for later identification by personnel in the Fisheries Institute at the University of British Columbia.

III. Results and Discussion

A. *General:*

Examination of data shown in Tables I and II show that 809 (7.6 percent) of a total of 10,676 shots killed or injured 59,277+ fish. Herring and rockfish constituted 72.2 and 23.8 per cent respectively of the total kill with the remaining four per cent comprising 189+ adult salmon, 467+ juvenile salmon and 1,732+ miscellaneous fishes. The total recorded mortality was considered a minimum estimate for the following reasons:

1. Estimates were based on surface observations only.

2. Field observations and available literature (Rulifson and Schoning, 1963) indicate that many dead or seriously damaged fish do not rise to the surface.

3. The low deck of the observation vessel provided limited observation. This condition was particularly critical in rough water and during twilight or early morning hours.

4. Mortality estimates included only those fish which rose to the surface during the observation period. Extended observation periods following completion of a shot pattern often doubled earlier estimates. However, these were not always included because wind and tidal action often distributed fish over a wide area making accurate estimates impossible.

Inspection of Table I, Table II and Figure 5 reveals that the percentage of shots which killed fish increased sharply when charges larger than 25 pounds were used. An extension of Table I into the individual tours as shown in Table III shows a consistent increase in the incidence of fish kill when charges of 50 pounds or more were used, except in tour eight. During this tour the increase

Table I.

Total Numbers and Percentages of Shots Resulting in Fish Mortality During Cruises One to Eight

Charge Size in Pounds of Nitrone	5	10	16⅔	25 or 26⅔	50	100	200	300	Total
Total Number of Shots	1251	2215	4727	1534	156	211	118	464	10,676
Total Number of Lethal Shots	21	99	200	82	49	101	57	200	809
Percentage of Shots Resulting in Fish Mortality	1.7	4.5	4.2	5.4	31.4	47.9	48.3	43.1	7.6

Table II.

Mortality Per Charge Size For Different Kinds Of Fishes

Charge Size Pounds	5	10	16⅔	25 or 26⅔	50	100	200	300	Total	Per-cent-age
Rockfish	13	255	804	287	37	890	214	11,659	14,159	23.8
Herring	139	1,275	1,519	3,246	3,189	16,420	7,074	9,818	42,730	72.2
Adult salmon	6	9	50	33	14	16	9	45	189	0.3
Juvenile salmon	1	0	143	60	20	46	98	99	467	0.8
Miscellaneous*	0	268	281	241	89	249	166	438	1,732	2.9
Totals	159	1,807	2,797	3,867	3,349	17,621	7,618	22,059	59,277	
Percentage of total kill	0.3	3.0	4.7	6.5	5.6	29.7	12.9	37.2		

*Needle Fish, Mackerel jack, Whiting, Grey Cod, Pacific Hake, Sea Perch

Table III.

Numbers and Percentages of Shots Resulting in Fish Mortality During the Eight Cruises of 1963

	Charge Size in Pounds								
Cruise	5	10	16⅔	25 or 26⅔	50	100	200	300	Total
1									
Number of shots	3	20	86	17	8	31	8	23	196
Number of lethal shots		1	1	1	2	17	4	15	41
Percentage of shots resulting in mortality		5.0	1.2	5.9	25.0	55.0	50.0	65.2	20.9
2									
Number of shots	24	400	366	388	18	30	11	77	1314
Number of lethal shots		1	14	1	8	10	7	44	85
Percentage of shots resulting in mortality		.3	3.8	.3	44.4	33.3	63.6	57.1	6.5
3									
Number of shots	33	433	222	25	27	33	14	17	804
Number of lethal shots		3	5	1	6	18	9	11	53
Percentage of shots resulting in mortality		.7	2.3	4.0	22.2	54.5	64.3	64.7	6.6
4									
Number of shots	126	2	808	308	20	18	12	26	1320
Number of lethal shots	2	0	33	37	7	13	8	18	118
Percentage of shots resulting in mortality	1.6		4.1	12.0	35.0	72.3	66.6	69.2	8.9

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Table III (*Concluded*)

Numbers and Percentages of Shots Resulting in Fish Mortality During the Eight Cruises of 1963 (*Concluded*)

Cruise	Charge Size in Pounds								
	5	10	16⅔	25 or 26⅔	50	100	200	300	Total
5									
Number of shots	4		249	38	30	32	21	211	585
Number of lethal shots			5		3	5	4	57	74
Percentage of shots resulting in mortality			2.0		10.0	15.6	19.0	27.0	12.6
6									
Number of shots	3	5	1532	273	13	3	5	40	1874
Number of lethal shots			26	5			1	8	40
Percentage of shots resulting in mortality			1.7	1.8			20.0	20.0	2.1
7									
Number of shots	645	2	1433	468	21	44	47	70	2730
Number of lethal shots	18	1	98	26	10	25	24	47	249
Percentage of shots resulting in mortality	2.8		6.8	5.6	47.6	56.8	51.1	67.1	9.1
8									
Number of shots	413	1353	31	17	19	20			1853
Number of lethal shots	1	93	18	12	13	13			150
Percentage of shots resulting in mortality		6.9	58.0	70.5	68.4	65.0			8.1
Total number of shots per charge size	1251	2215	4727	1534	156	211	118	464	10,676

occurred when charges larger than 10 pounds were used. Much of this tour was conducted in the relatively shallow waters of Northern Hecate Strait and this may account for the increased lethality of 16⅔ pound charges.

It is interesting to note that Aplin (1947) later supported by the Chesapeake Biological Laboratory (Anon., 1948), found no apparent relation between water depth or charge size and fish mortality. Knight (1907) reported however, that destructiveness varied with charge size, water depth, number of fish present in the locality of explosion, distance of fish from the explosion site and kinds of fish present.

Table IV.

Comparison of the Observed Lethal Effect of Different Shot Patterns on Fish Populations

Shooting Pattern	Total Number of Shot Points	Number of Lethal Shot Points	Percentage of Lethal Shot Points
Refraction	81	56	69.1
Reflection	9,382	343	3.7
Velocity Profile	76	1	1.3
Hydrophone and Reverse Refraction	99	19	19.0
Total	9,638	419	

As shown in Table IV, 419 (4.3 percent) of a total of 9,638 shot points demonstrated fish mortality. The incidence of fish mortality was 18 times greater at refraction shot points than at reflection shot points. The incidence of fish mortality during the hydrophone and reverse refraction (heavy charges) shooting was five times greater than that for reflection shooting with light charges.

Inspection of Table V shows that 75 shot points accounted for 86.2 per cent of the total observed mortality. The remaining 13.8 per cent were distributed over 344 shot points which included all types of shooting. Nine refraction shot points accounted for 75.3 per cent of the total observed mortality. In all cases single or multiple shots of heavy charges on a shot point resulted in a consistently higher mortality than for shot points subjected to light charges.

Table V.

Analysis of the 15 Refraction and Reflection Shot Patterns Which Resulted in Major Fish Kills

Shooting Pattern	Herring Mortality	Rockfish Mortality	Total	Percentage of Total Mortality	Number of Lethal Shot Points	Number of Kills Detected on the Scanner	Number of Shot Suspensions
Refraction	36,244+	8,374+	44,618+	75.3	9	11	5
Reflection	2,155+	702+	2,857+	4.8	61	32	
Hydrophone Refraction		2,640+	2,640+	4.4	4		
Velocity Profile	1,000+	—	1,000+	1.7	1		
Totals	—	—	51,115+	86.2	75	43	5

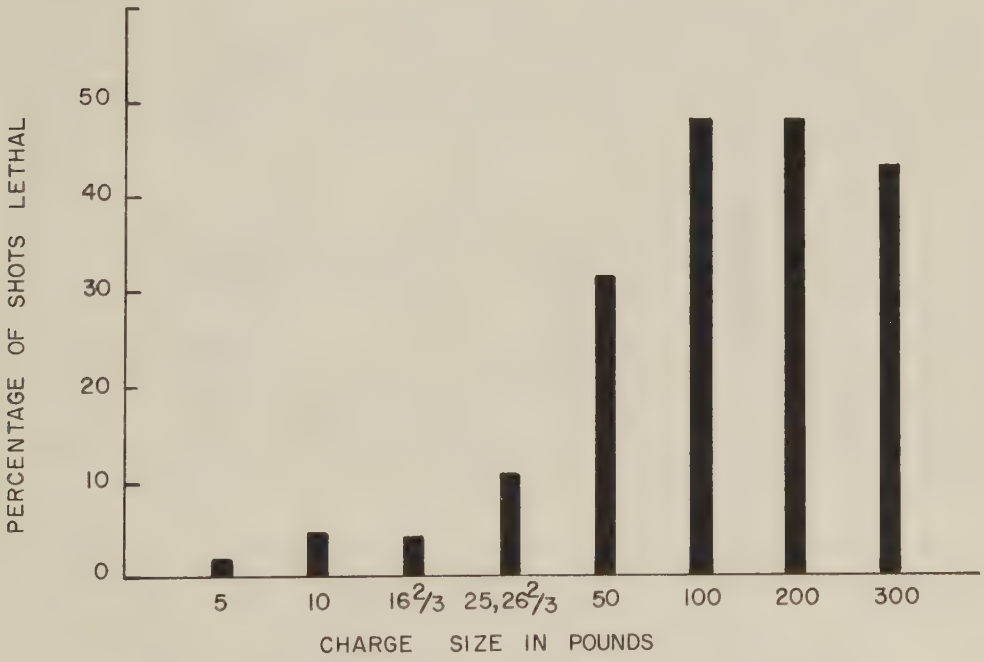

FIGURE 5. *Percentage Comparison of Lethal Shots for Various Charge Sizes.*

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B. *Effect of Water Depth on Incidence of Mortality:*

Table VI and Figure 6 show that the increased lethal effect of light charges on fish located in shallow water (less than 34 fathoms) is greater than that on fish in deep water (more than 34 fathoms). Every shallow water shot point involving charges of 5, 10, $16\frac{2}{3}$ and 25 pounds resulted in fish mortality, whereas charges of the same magnitude at deep water shot points demonstrated a much lower incidence.

Table VI.

Comparison of Lethal Effects of Light Charge Refraction Shots Detonated at Shallow and Deep Water Shot Points[1].

Charge Size in Pounds	Shallow Water (less than 34 fathoms)		Deep Water (greater than 34 fathoms)	
	Number of Shot Points	Number of Lethal Shot Points	Number of Shot Points	Number of Lethal Shot Points
5	1	1	3	0
10	4	4	19	0
$16\frac{2}{3}$	6	6	41	5
25	10	10	45	8

[1]Fish were present at all shot points as revealed by surface mortality occurring after detonation of heavier charges.

Table VII also supports the conclusion that incidence of fish mortality is greater in shallow water. Ten pound charges detonated in shallow water killed approximately 14 times as many fish as the deep water shots. In shallow water an increase in charge size from five to ten pounds resulted in a fourfold increase in the incidence of lethal shots.

Table VII.

Comparison of the Incidence of Mortality Resulting from Detonation of Light Charges in Shallow and Deep Water During Reflection Shooting

Charge Size in Pounds	Shots Detonated in Shallow Water (less than 34 fathoms)			Shots Detonated in Deep Water (greater than 34 fathoms)		
	Number of Shots	Number Killing Fish	Percentage	Number of Shots	Number Killing Fish	Percentage
5	1206	18	1.49	33	0	—
10	1322	89	6.67	818	4	.49
$16\frac{2}{3}$	45	1	2.22	4561	173	3.79
25	—	—	—	1300	59	4.53

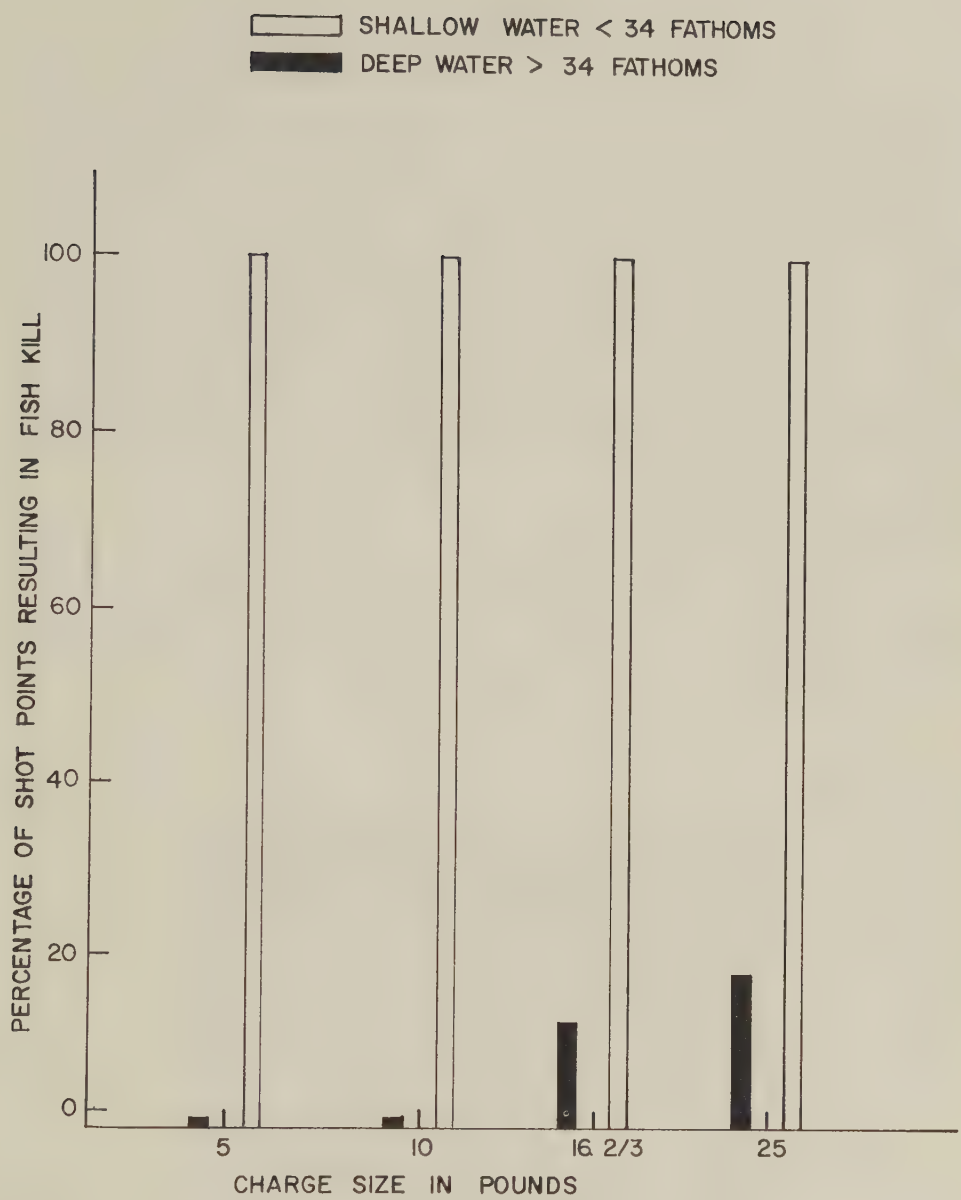

FIGURE 6. *Percentage Comparison of Explosion Effects at Deep and Shallow Water Shot Points.*

The foregoing is supported by previous investigators who have pointed out that enclosed areas such as underwater canyons and shallows tend to reflect seismic shock waves more readily than unconfined water areas and they therefore amplify the lethal effects of underwater explosives (Hubbs and Rechnitzer, 1952).

C. *Lethal Range Analysis:*

In cases where fish were located at the same depth and distance from the shot point, light charges used in refraction shooting were lethal to fish whereas those used in reflection shots were not. This is demonstrated by the following examples in which the horizontal distances have been estimated. Refraction charges of 25 pounds set to explode 32 feet from the surface killed fish which were located at 240 feet depth and approximately 850 feet from the shot point, although the same charge employed in reflection shooting, but set to explode four feet from the surface, did not kill fish located at 240 feet depth and 100 feet from the shot point. Knight (1907) reported that fish mortality increases as the detonation depth of dynamite charges increases. There is thus some evidence that charges of the same magnitude set to explode at greater depths are more lethal to fish populations than those exploding at shallow depths. Charges set at shallow depths lose more shock wave energy at the surface than deep set charges. Consequently less energy is directed below the surface which in turn is less lethal to fish populations.

D. *Analysis of Fish Mortality Samples:*

Examination of Table VIII shows that all 25 species killed by the seismic explosions possessed an air bladder. It is also believed that only those fish with air bladders were observed on the surface throughout the duration of the survey. Literature reviews show that bladderless fish are not as adversely affected as fish with air bladders (Rulifson and Schoning, 1963).

Examination of fish killed by seismic explosions revealed specimens with internal ruptures, displaced visceral organs, torn musculature, haemorrhaging blood vessels, protruding eyes, everted stomachs and gas bladder damage. Observations from the Chesapeake Biological Laboratory (Anon., 1948) revealed that exposure of fish to explosions usually results in rupture or haemorrhage of the gas bladder, abdominal vein, spleen, liver and ripe gonads. Severe damage to any one organ is usually fatal, but moderate or slight injury is often survived. The organ most commonly damaged was the gas bladder. Post mortem observation showed that the edges of holes in the gas bladder were turned outward and that blood from broken vessels in the wall of the bladder had been blown into the abdominal cavity. Such evidence suggests that ruptured or distended gas bladders are caused from an increase of internal pressure from within rather than without.

Examination of gas bladder damage provided the basis for the following conjectures: herring and salmon usually suffered ruptured gas bladders which may be the direct result of the explosion pressure wave. Tyler (1960) reported that caged salmon subjected to dynamite explosions exhibited ruptured gas bladders. Both fishes exhibit the physostomous condition in which the gas bladder is connected to the esophagus by a pneumatic duct. Such a connection would permit a severe pressure change to directly enter the gas bladder. In the event that the gas bladder does not, or cannot, adjust to a sudden pressure difference, serious damage such as a rupture could occur. The released gas could

escape into the abdominal cavity and considerably increase the buoyancy of the fish. The buoyancy period was extremely short for salmon which, if they came to the surface at all, remained there for only a few minutes; whereas herring exhibited a longer buoyancy, frequently in excess of one hour.

Rockfishes often showed portions of the stomach extending into the mouth cavity (Figure 7). Dissection revealed that this stomach protrusion was caused by a greatly distended gas bladder which had forced the stomach anteriorly. Since rockfish exhibit the physoclistous condition (no connecting pneumatic duct between gas bladder and esophagus), they would not react to presssure differences in the same way as herring or salmon do. Since the gas bladder is under the control of the central nervous system, damage to this system caused by a seismic shock wave could conceivably relax hydrostatic control. Ward, Montgomery and Clark (1948) have presented a theory of the mechanism of the nervous system damage which results from an intense positive pressure wave followed by negative pressure. They postulate that such injury occurs in the negative phase of the pressure wave, and results directly from the process of cavitation, or the rapid formation and collapse of cavities in the brain fluids. Rockfish disorientated in this fashion could rise to the surface. If the rate of ascent was faster than the pressure adjustment capacity of the rockfish, the gas bladder would expand and displace internal organs as exhibited by the everted stomach. In this case hydrostatic control may be lost indirectly through destruction of central nerve control. Salmon and herring lose hydrostatic control because of the pressure wave entering the gas bladder through the pneumatic duct and directly rupturing the gas bladder.

FIGURE 7. *Samples of rockfish mortality showing protruding eyes, everted stomachs and gill haemorrhage.*

Table VIII.

List of Fish Species Killed by Seismic Explosions

Number of Specimens	Species	Common Name
1	Sebastodes alutus	Longjaw rockfish
1	" entomelas	Widow rockfish
2	" mystinus	Blue rockfish
10	" zacentrus	Sharpchin rockfish
1	" pinniger	Orange rockfish
1	" nigrocinctus	Blackbanded rockfish
2	" ruberrimus	Red snapper
2	" helomaculatus	Rosethorn rockfish
4	" brevispinus	Shortspine rockfish
2	" melanops	Black rockfish
8	" proriger	Redstripe rockfish
2	" caurinus	Copper rockfish
3	" flavidus	Yellowtail rockfish
2	" maliger	Quillback rockfish
1	Hexagrammos decagrammus	Kelp greenling
1	Theragra chalcogrammus	Whiting
3	Gadus macrocephalus	Pacific cod
1	Trachurus symmetricus	Mackerel jack
1	Merluccius produtuctus	Pacific hake
1	Oncorhynchus tshawytscha	Spring salmon
8	Oncorhynchus nerka	Sockeye salmon
14	Cymatogaster aggregata	Shiner seaperch
1	Ammodytes hexapterus	Pacific sandlance
1	Aulorhynchus flavidus	Tube snout
30	Clupea pallasii	Pacific herring

E. *Utilization of the Fish Detection Unit:*

An analysis of the recordings from the Kelvin Hughes Ceres Fish Recorder demonstrated that the vertical echo sounder was the only functional component which provided useful and accurate data concerning fish indications. The horizontal and angle asdic scanners gave no satisfactory results. During refraction shooting horizontal scanning showed some excellent tracings which were first interpreted as indications of fish presence. However, these tracings showed up each time that the shooting vesssel returned for another pass over the shot point. It was also noted that after the first shot in a refraction series these tracings began to appear as the shooting vessel returned to the boil of the shot point. It was reasonable to assume that these tracings were the result of the sonar sound waves reflecting off water turbulence caused by previous shots and if there were fish present in the "boil" area they were not discernible on the horizontal scanner. The extent of turbulence resulting from detonations of small and large charges is indicated in Figure 8.

No fish were located by the horizontal scanner, followed through to the angle scanner and then picked up on the vertical scanner. During reflection shooting the vertical recordings gave the most reliable data for lethal distance calculation since the ship travelled at a constant speed and fish position could be determined on both horizontal and vertical planes. Fish scanner data correlated with observed mortality showed that herring schools were the most

(a)

(b)

(c)

FIGURE 8. *Surface disturbance following detonation of:*
(a) *16⅔ pound charge suspended three feet below surface.*
(b) *300 pound charge suspended 40 feet below surface.*
(c) *boil area following detonation of 300 pound charge.*

readily detected whereas rockfish showed up only occasionally. No fish indications were positively correlated with salmon kills. Fish schools were readily detected while indications of single fish were not confirmed.

In eleven out of the 15 major kills, (see Table V) fish presence was indicated on the recording tape before and/or during shooting. In five of those eleven cases the fish mortality was considered excessive and the shot pattern was suspended. On some occasions the observer refrained from requesting shot suspension despite indications of fish on the detection unit for the following reasons:

1. Indications on the recorder did not reveal actual size of the fish schools. In many cases only a small part of a school was detected, especially in those instances when fish apparently were located quite close to the surface, as revealed by dead or injured fish appearing on the surface within one or two minutes.

2. Experience had demonstrated that interpretation of every "blip" on the recorder as an indication of fish presence was not valid as a significant number of false echoes and interference made such interpretation highly questionable.

3. In several cases excellent recordings of fish presence were not substantiated by surface observations of mortality.

4. In many cases where the accumulated fish kill was small, the observer permitted shooting to continue as long as mortality did not exceed more than a few hundred fish depending on the species. In other cases where the first few shots produced light mortality but subsequent shooting did not, the shot pattern was permitted to continue.

5. Shooting patterns during initial cruises were not interrupted or suspended, since the observer wished to determine the lethal effect of various charge sizes on fish populations, and evaluate the usefulness of the fish detection unit by correlating fish indications with surface mortalities.

Examination of 61 reflection patterns showed that 78 fish kills (36.3 percent) out of a total of 215 were detected on the Kelvin Hughes Recorder. The detection efficiency was found to vary with the rate of sound impulse, water depth, and fish species. Very satisfactory results were obtained in a reflection series completed in 10 to 15 fathoms of water. On this line 32 (58.2 per cent) observed fish kills out of a total of 55 were detected. The increase in detection efficiency is probably related to the increased pulse rate of sonar transmission required when working in shallow water.

It is evident that the operator of the Ceres Fish Recorder was using an instrument under operational conditions for which it was not intended. This was largely due to the limited maneuvers of the shooting vessel (which did not permit homing on fish schools) and the successive shots at refraction shot points which masked the shot point area with water turbulence. In reflection shooting the advance position of the instrument vessel interfered with the fish scanner's horizontal beam in that echoes were reflected off the instrument vessel propellers and prop wash and masked any recorder indications of fish.

F. *Diver's Assessment Program:*

The area chosen for the diver's assessment program was not abundantly populated with fish and the strong tidal currents limited the accuracy of distance estimates by the divers. Only one out of eight proposed shot points demonstrated fish presence on the vertical scanner. Since fish were of limited abundance five shots were made at this single shot point located in 60 feet of water. Pre- and post-examination data for each shot appear in Table IX. The results reveal that five and ten pound shots killed rockfish and sculpins within a 25-foot radius of the shot point and that a $16\frac{2}{3}$ pound shot killed rockfish and salmon within a 50-foot radius. The $16\frac{2}{3}$ pound shot had no effect on gas-bladderless fish, which included a few sculpins, one flatfish and five dogfish sharks, located approximately 50 feet away from the shot point. Aplin (1947) reported that 20

Table IX.

Results of the Diving Assessment Program

Charge Size lbs.	Fish Observed in Test Area			
Detonation Depth Feet	Radial Distance From Shot Point	Before Detonation	After Detonation	
			Alive	Dead
5/3	25′	needlefish sculpin lingcod	1 rockfish 4 sculpin	2 sculpin 1 rockfish
	50′		—	—
	75′		—	—
10/20	25′	sculpin lingcod rockfish	1 flatfish 7 sculpin	5 rockfish
	50′		—	—
	75′		—	—
$16\frac{2}{3}$/20	25′	rockfish lingcod	rockfish lingcod	1 rockfish 2 salmon
	50′		sculpin 1 flatfish 5 dogfish	
	75′		—	—
25/32	25′	rockfish lingcod		1 salmon smolt (surface)
	50′		3 sculpin	—
	75′		1 lingcod 5 sculpin 1 crab	—
50/40	25′	sculpin lingcod	—	—
	50′		—	—
	75′		—	—

pound charges of dynamite exploded four feet below the surface, at horizontal distances of 50 and 55 feet from caged fish, killed those with gas bladders but had no effect on gas-bladderless halibut and sculpins.

Of 11 dead fish accounted for, only one, a juvenile salmon, appeared on the surface. Two adult salmon, six rockfish and two sculpins were retrieved from the bottom at a depth of 10 fathoms. The last detonation, a 50 pound charge set to explode at 40 feet, had sufficient force to remove shellfish from rocks and split large boulders, but had no effect on gas-bladderless lingcod and sculpins located 50 to 100 feet away from the shot point. Thompson (1958) reported that 2,750,000 pounds of high explosive used to remove Ripple Rock, a navigation hazard in Canada, killed rockfish but did not kill lingcod located in cages $\frac{1}{2}$ mile away. One live crab apparently unharmed was found within the 50–100 feet radius of the 50 pound explosion.

The decrease in lethality is related to a sharp dissipation of pressure as the distance away from the explosion increases (Hubbs and Rechnitzer, 1952). The two dead sculpins (not identified as to species) which were within 25 feet of the shot point anchor were killed by a five pound charge set to explode at three feet from the surface. However, a 25 pound charge with a detonation depth of 32 feet did not kill two sculpins located within 25 feet of the shot point. This disparity may be attributed to the difficult observation conditions and the resultant inaccuracy in distance estimations.

Despite the paucity of the above data it is quite obvious that surface observations are not a reliable method for determining the total effect of a seismic explosion on fish because they do not account for subsurface mortality. A supporting view comes from Ferguson (1961) who noted that the number of fish which had been killed by seismic explosions and which had floated to the surface were not a reliable measure of charge lethality because of variations in fish abundance and distribution.

IV. Summary of Results

During the 1963 Shell Oil Seismic Program, 809 (7.6 percent) of a total of 10,667 detonations killed 59,277+ fish. Herring and rockfish represented 72.8 and 23.8 percent respectively of the total kill, with the remaining 4.2 percent consisting of 189+ adult salmon, 467+ juvenile salmon, and 1,732+ miscellaneous fishes. All fishes examined or observed possessed air bladders.

The total mortality of 59,277+ fish was regarded as minimal principally because estimates were based on surface observations only.

Light nitrone charges (5–25 pounds) have the capacity to kill fewer fish and less often than heavy charges (50–300 pounds). There was evidence that for a given charge size, an increased detonation depth results in an increased incidence of mortality. The occurrence of mortality resulting from light charges increased sharply when explosions were detonated in relatively shallow water (less than 34 fathoms).

A total of 10,676 charges of nitrone explosives were exploded at 9,638 shot points. Only 419 shot points (4.3 percent) showed evidence of fish mortality,

and seventy-five of these accounted for 86.2 percent of the total kill. Nine refraction shot points accounted for 75.3 percent of the total mortality. Refraction profile shooting patterns, which always involved detonation of heavy charges, killed the greatest numbers of fish and appear to be the greatest threat to fish populations.

Analysis of recordings from the Kelvin Hughes Ceres Fish Detection Unit demonstrated that the vertical scanner was the only functional unit which provided useful and accurate data concerning fish indications and their location. The horizontal and angle asdic scanners gave no satisfactory results. Recordings showed that herring schools were the most readily detected while rockfish were only occasionally detected. No observed salmon kills were correlated with indications on the recording tape. As the operator gains experience with the machine, sizeable fish indications on the recorder can be interpreted with sufficient confidence to recommend shot suspension.

Analysis of the Diving Assessment Program showed that of 11 dead or seriously damaged fish found during post-explosion examinations, only one was observed on the surface. The lethal effect of nitrone charges on fish populations sharply decreased with increasing distance from the shot point. Fish without gas bladders such as flatfish and lingcod were relatively unaffected by seismic explosions.

V. Conclusion

While supervision and control were the principal responsibilities of the Department's observer staff, additional information was obtained in connection with the effects of underwater explosions on fish populations.

A total of 10,676 shots at 9,638 shot points exhibited an observed fish kill at 419 shot points. The total surface mortality amounted to 59,277+ fish. Herring and rockfish represented 72.2 and 23.8 percent of the total kill respectively with the remaining four percent consisting of 189+ adult salmon, 467+ juvenile salmon and 1,732+ miscellaneous fishes. Large charges (50–300 pounds) typical of refraction shooting killed more fish more frequently than the light charges (5–25 pounds) which were typical of reflection shooting. Increasing the charge detonation depth will increase the potential area of fish kill. In shallow water the horizontal lethal range of a seismic charge is greater than in deep water. Surface observations of fish mortality were not a reliable measure of charge lethality because they did not account for subsurface mortality. Only the vertical scanner on the fish detection unit was found useful in detecting the presence of fishes.

Considering the extent of the area explored and the number of shot points subjected to high velocity explosives, the resulting fish mortality may be considered relatively light (even when magnified by the unobserved mortality). Fishes of commercial value were not seriously affected by the 1963 seismic survey. However, it was obvious that nitrone explosives on several occasions killed large numbers of fish.

The fact that a high mortality to fish was not evident can probably be attributed to the conditions agreed to by the Company and the Department.

The excellent co-operation developed in this program resulted in the Company and the Department achieving their respective goals of oil exploration and maximum protection to the fishery resource.

Acknowledgments

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A Device for Injecting Juvenile Fish Into a Pressure Conduit

by

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Abstract

An apparatus for safely injecting live fish into a high pressure water conduit without allowing the fish access to a free air surface while under increased pressure is described.

The injection gear described was designed and built for a series of fish passage tests being conducted at the University of British Columbia on a 10-inch diameter Kaplan turbine. In order to simulate the conditions experienced by a fish when being carried from a reservoir down a penstock and through a turbine, the injection gear was designed to prevent the fish, or water in which they are held, from contacting air under pressure during the injection process.

When the water pressure on a fish is increased, the volume of its swimbladder decreases according to Boyle's Law. The fish as a result loses its equilibrium and tends to sink. Some fish (physostomes) are able to swallow air at the surface and pump it into the swimbladder via the pneumatic duct to maintain their equilibrium (Jones, 1957). While salmon are physostomes, i.e. have open swimbladders, Bishai (1961) has demonstrated that among physostomes the ability to adjust buoyancy by forcing air through the pneumatic duct varies both with species and with the age of the fish. It was necessary to eliminate this unknown from the tests for the following reason.

In the event that a fish, during the injection process, was able to inflate its swimbladder with air under greater than atmospheric pressure, then as it passed through the turbine and returned to atmospheric pressure and possibly experienced moments of considerable negative pressure it is far more likely to rupture its swimbladder than a fish which has not had access to air under pressure. The injection gear was designed to avoid this possibility.

The injection gear was installed as shown in Figure I in the hydraulics laboratory of the University of British Columbia. A two-foot long section of acrylic pipe 14 inches in diameter was also installed downstream of the injection gear to permit observation of the behaviour of the fish as they encountered the fast-flowing water in the penstock.

Clear acrylic plastic was used to fabricate the injection gear (Figure 2). This permitted visual observation of the fish throughout the complete injection

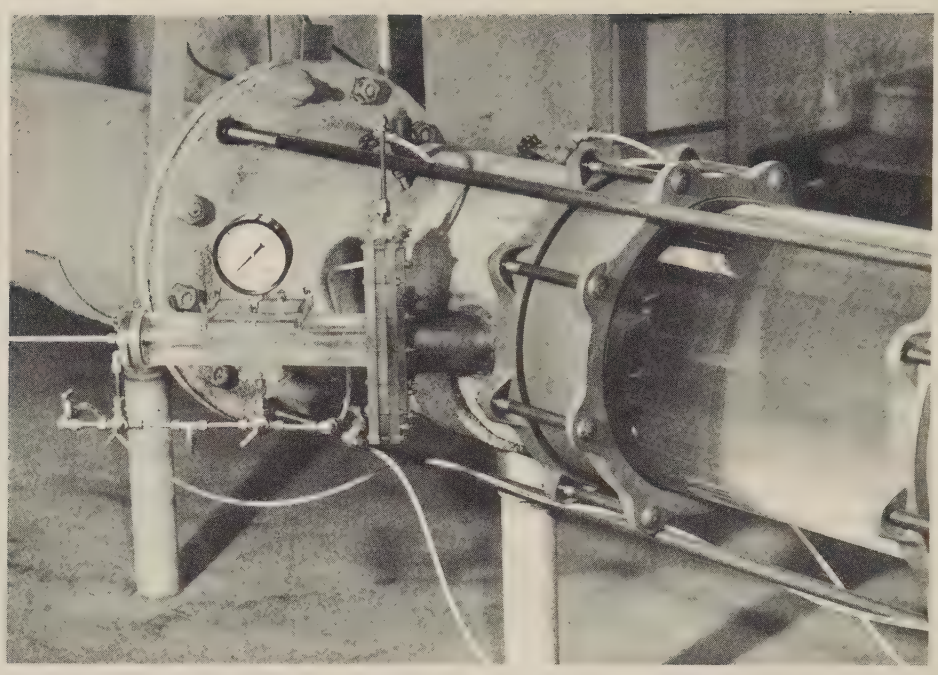

FIGURE 1. *Injection gear installed on penstock leading to a ten-inch Kaplan turbine in the University of British Columbia hydraulics laboratory. Flow in the penstock is from left to right*

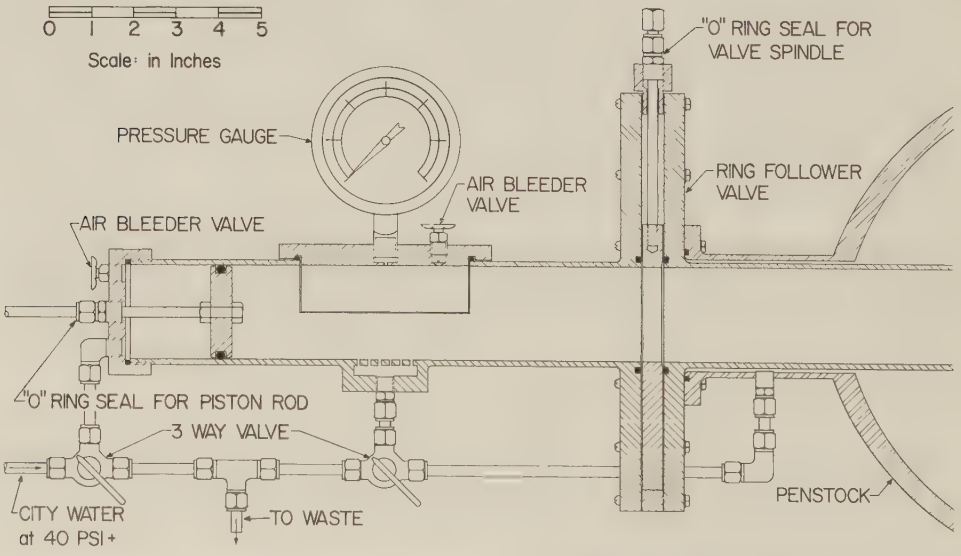

FIGURE 2. *Section through centreline of injection gear. Black dots indicate "O" ring seals. Injection gear set at 45° to centreline of the penstock, pointing downstream. Fish are released at the centre of the penstock.*

process. One-eighth inch thick by $2\frac{1}{2}$ inch outside diameter acrylic tube forms the body of the gear. A safety valve in the turbine water system limited the maximum possible water pressure at the injection point to 26 psi.

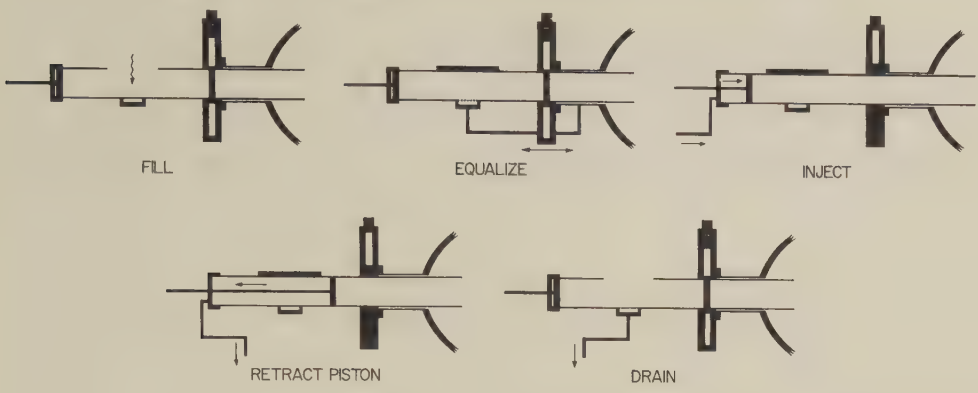

FIGURE 3. *Operating Sequence*

The method of operation is shown diagrammatically in Figure 3. After filling and closing the cylinder all air was expelled via the two air bleeder valves before the pressure on the fish was raised to that of the penstock. The city water pressure exceeded the penstock pressure so it slowly forced the piston through the injection gear expelling the fish into the penstock. A stop on the end of the piston rod was set to limit the pistons' travel to a point where the city water could escape past the piston "O ring" at the 45° cut at the end of the cylinder. This prevented higher than penstock pressures from occurring in the gear. Penstock pressure forced the piston to retract when the water behind it was allowed to drain out. During the operating sequence the ring follower valve was operated only when pressure was equal on either side so little effort was necessary to move it.

The unit has been in operation for one testing season, with 8000 pink, chum and coho salmon fry from 33 to 46 mm in length having been passed through it in lots of 80 fish each, without damage.

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A New Distribution Record for *Myxosoma scleroperca* Guilford, 1963 (Sporozoa; Myxosomatidae) in Yellow Perch of Lake Erie.[1]

by

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Guilford (1963) described *Myxosoma scleroperca* from the sclerotic cartilage of yellow perch, *Perca flavescens*, and from logperch, *Percina caprodes*, from Green Bay, Lake Michigan. This parasite (Figure 1) was found in the sclerotic cartilage of yellow perch from the Canadian waters of Lake Erie during 1961–1963 investigations.

Both regularly and irregularly shaped vegetative cysts from 0.1 to 5.2 mm in diameter occurred in the dorsal and ventral parts of the eye. Occasionally posterior portions of the eye were infected (Figure 2). The spore dimensions, the capsular filaments with 6 to 9 coils, and the small karyosomatic nuclei in the sporoplasm conformed to the description given by Guilford (1963).

The degree of infestation for Lake Erie perch is compared to Guilford's data for Green Bay perch in Table I. The degree of infestation was higher in Lake Erie and was increasing in both areas during the period under discussion. No perch under $4\frac{1}{4}$ inches fork length was found infected. The parasitization was heavy enough to seriously affect the eyes of some perch.

[1]Contribution No. 64-16 from the Ontario Department of Lands and Forests, Research Branch, Maple, Ontario.

Table I.

The incidence of *M. scleroperca* in yellow perch

Year	L. Erie								L. Michigan
	Number Examined	Number Infect.	Frequency %	Concen. Index	Location cysts in eyes				Frequency %
					Vent.	Dor.	Ant.	Post.	
1961	70	14	20	4.3	4	10	12	2	6.6
1962	50	11	22	8.6	3	8	7	4	11.2
1963 (Jan-June)	25	6	24	11.2	6	4	5	3	

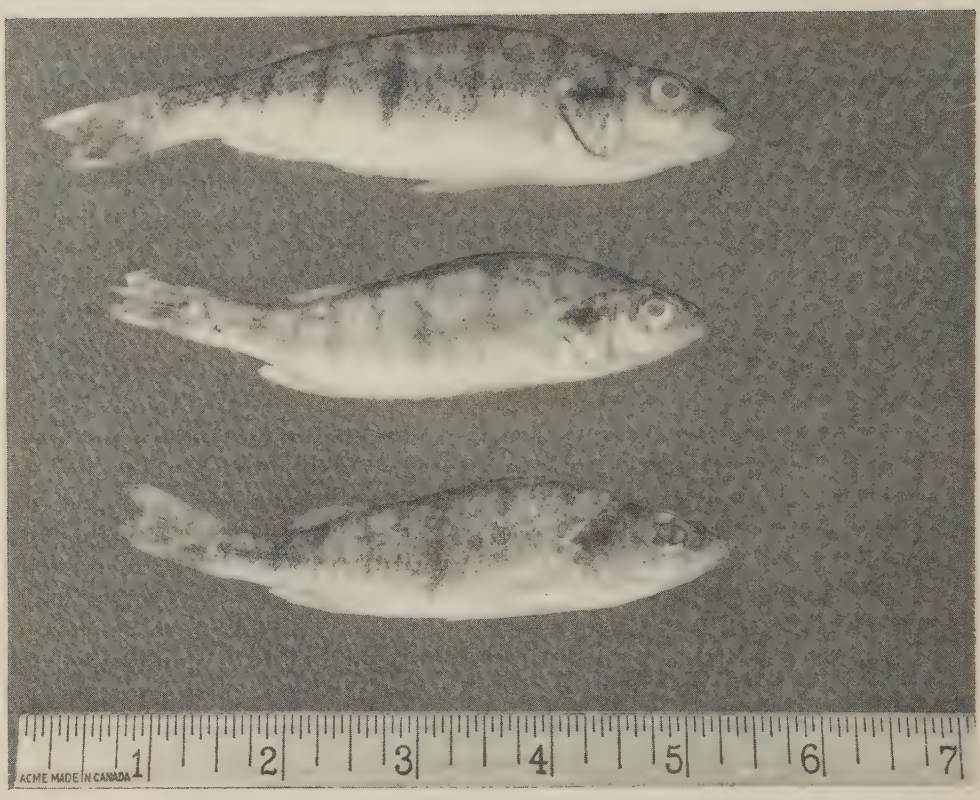

FIGURE 1. *Yellow perch with cysts of* M. scleroperca *present in dorsal and ventral parts of eyes.*

Guilford (1963), describing *M. scleroperca* reviewed the literature on related myxosporidians occurring in the skeletal cartilage or in the eyes of various fishes. He mentioned: 1. *Myxosoma* (*Lentospora*) *cerebralis*, Hofer, (1903), from the cartilage of young salmonids (primarily of the head); 2. *Myxosoma* sp. Hoffman, Dunbar and Bradford (1962), from the head cartilage of *Lepomis macrochirus*; 3. *Myxobolus aeglefini*, Auerbach (1906), from the head skeleton of *Gadus* and other marine fishes; 4. *M. couesius* Fantham, Porter and Richardson (1939) from the iris of *Couesius plumbeus*; 5. *M. magnus*, Averintzew (1913), from the iris of *Acerina acerina*; (To my knowledge Averintzew has described *M. magnus* not from *A. acerina* (Güldenstädt) as stated by Guilford, but from *A. cernua* (Linné), the ruffe (Markewich, 1951).

Guilford did not mention four other myxosporidians parasitizing eyes of fishes: 1. *Myxobolus volgensis*, Reuss (1906), from the cornea, skin, gills, fins and muscles of *Lucioperca lucioperca*, *L. volgensis* and *Acerina cernua* in Europe; 2. *M. talievi*, Dogiel, Bogolepova and Smirnova (1949), from the eye of cottids in Lake Baykal, a species causing exophthalmus and blindness; 3. *M. spatulatus*, Dogiel, Bogolepova and Smirnova (1949) parasitizing the eyes of the cottids with similar pathogenicity; 4. *M. schizura*, Gurley (1893), which encysts on sclerotic and between sclerotic and choroid in *Esox lucius*, but which seems to cause no noticeable pathological changes.

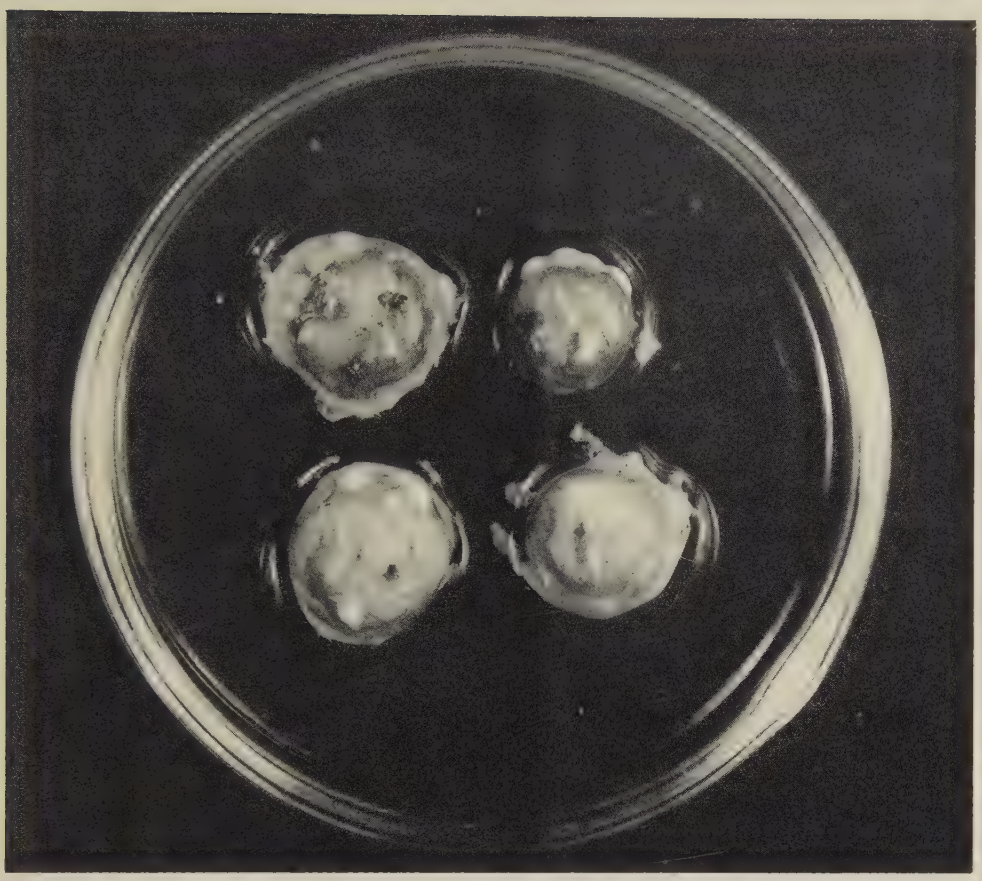

FIGURE 2. *Cysts of* M. scleroperca *on posterior portion of eyes from yellow perch.*

Since the development of *M. scleroperca* is not dependent upon an intermediate host, and since yellow perch are currently abundant in Lake Erie, it is considered likely that the rate of infestation with this parasite will continue to increase.

Acknowledgements

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Preliminary Observations on *Glugea hertwigi*, Weissenberg, 1911 (Microsporidia; Glugeidae) in American Smelt, *Osmerus mordax* (Mitchill) from Lake Erie[1]

by

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Glugea hertwigi, Weissenberg (1911), was first noted in Lake Erie smelt in 1960. Its occurrence there has been followed each year since.

In April 1960 a smelt, taken from the Wheatley area of Lake Erie was found to contain 30 cysts of *G. hertwigi*. In this and subsequent specimens cysts were found on the viscera, usually on the gonads (Figures 1 and 2). The white cysts measure from 0.2 to 3.5 mm (average–3.0 mm) and are often numerous, up to 60 per fish. Spores measure 3.3–4.4 × 2.0–2.6 microns. The infestation rate of Lake Erie smelt has been as follows: 1960—two infected in a sample of 16; 1961—two infected in a sample of 15; 1963—three infected in a sample of 20; 1964—4 infected in a sample of 50. Infected fish have been recorded each month from March through July and from the Port Dover as well as the Wheatley area of Lake Erie. Only adult and sub-adult smelt at least five inches long were found to be parasitized.

G. hertwigi is an holarctic species. Several authors have reported its occurrence in Europe and Markevich (1951) reported its occurrence in the far east and in North America. It is a pathogenic parasite. Haley (1952), attributed smelt mortality in Loon Pond, New Hampshire to *G. hertwigi*. Barycheva and Bauer (1957), pointed out that heavy infections can cause mortality in smelt. It is likely that severe infections can seriously affect the normal functions of the intestine. Fantham et al (1941), Nigrelli (1953), and Sinderman (1963) stressed the severity of pathological changes caused by *G. hertwigi*.

Further studies are necessary to assess the occurrence of *G. hertwigi* in the smelt population of Lake Erie and to record seasonal changes in the rates of infection.

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The author is grateful to Mr. C. Gamble, Mr. L. Omstead Jr., Mr. D. Getty, Dr. R. G. Ferguson and to the staff of the Wheatley Fisheries Research

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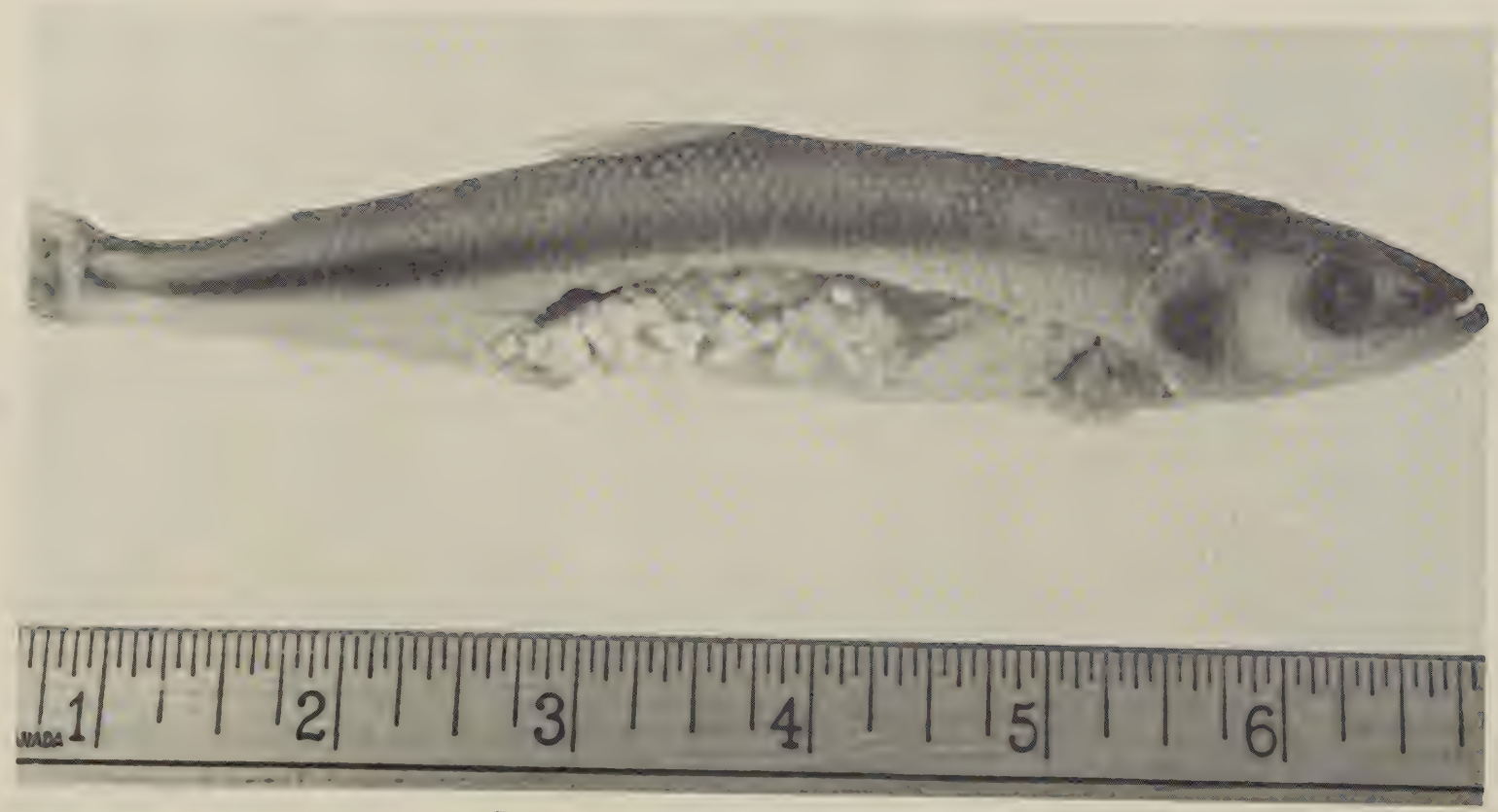

FIGURE 1. *Smelt showing advanced infection of ovary*

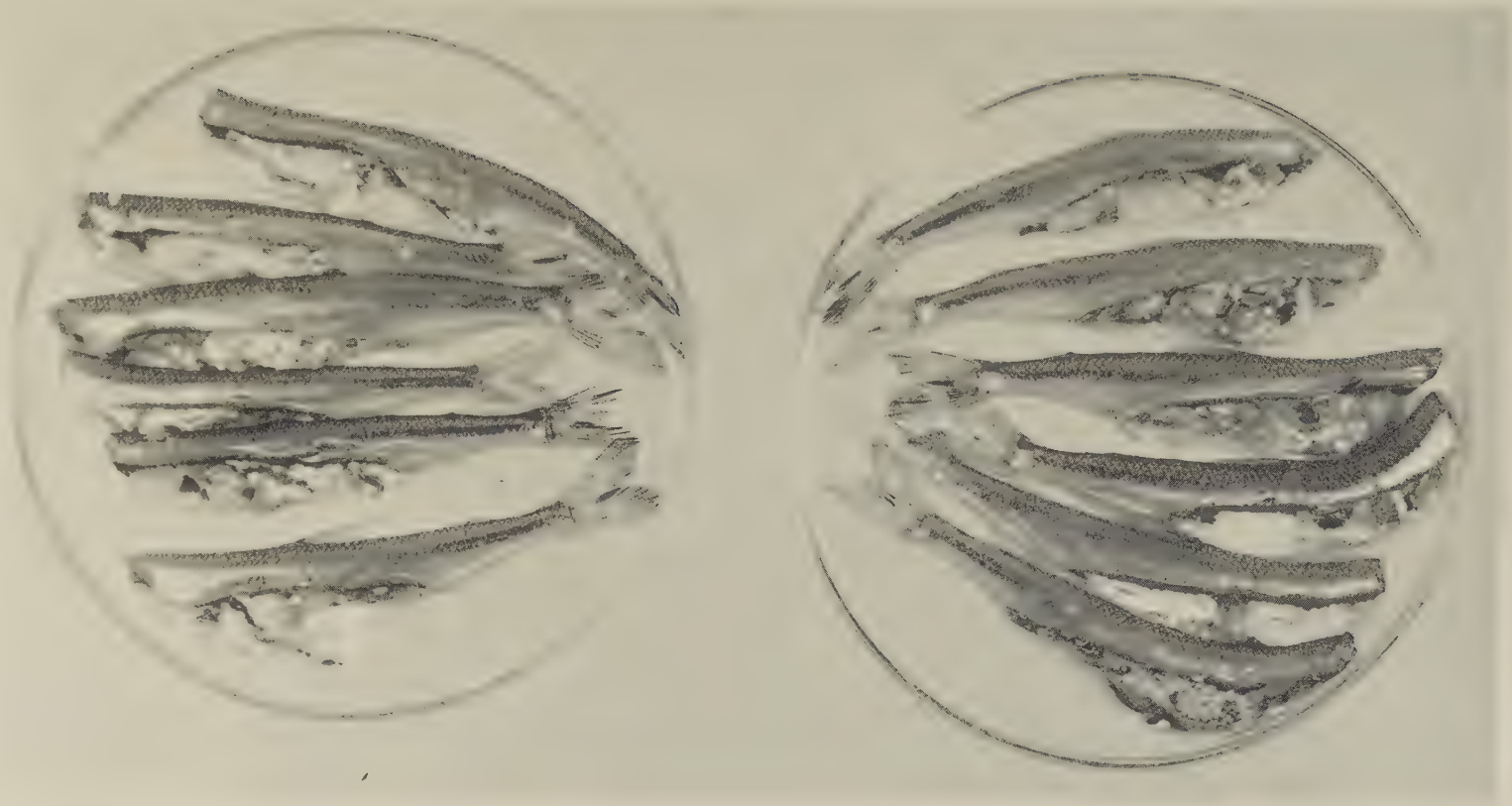

FIGURE 2. *Smelts showing advanced infection of liver, ovary and intestine.*

Station for their kindness in supplying specimens. I wish also to express sincere thanks to Miss J. Robinson, Canada Department of Forestry, for taking the photographs.

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Book Review

Fishes Occurring in the Fresh Waters of Insular Newfoundland, by W. B. Scott and E. J. Crossman. The Department of Fisheries of Canada. Available from the Queen's Printer, Ottawa. $3.00.

Prior to the appearance of this publication information on fishes of Newfoundland was scattered through numerous short papers and reports. *Fishes Occurring in the Fresh Waters of Insular Newfoundland* is therefore a most welcome arrival which will be invaluable to scientists, field officers, sportsmen and naturalists interested in fishes of the Atlantic area.

Drs. Scott and Crossman have explained that their contribution deals only with fishes of insular Newfoundland since those species found in Labrador, the mainland portion of the province, are typically mainland Canadian. The authors have combined findings from their 1960 field work with historical writings from various sources. The combination of recent and early survey findings gives the publication depth and interest to the casual reader as well as practical value to the present day investigator.

Fishes Occurring in the Fresh Waters of Insular Newfoundland contains a list of the 23 species known to exist in fresh waters of Newfoundland. The authors have included a general key to the fishes found in the area as well as specific keys where families having a number of representatives are treated. There is a section containing write-ups on each species and a number of appendices dealing with various aspects of the subject. The text is accompanied by a number of tables and figures which include photographs of many of the species described. Also included are photographs showing views of lakes and streams of insular Newfoundland where the authors undertook many of their collections.

Sections dealing with species of major importance are introduced by a paragraph on the historical findings and occurrences. This is followed by "Distribution", "Description", "Spawning", "Food", "Growth", etc. Species occurring only occasionally in the area's fresh or brackish waters are treated briefly by a report of their occurrence in historical records.

Drs. Scott and Crossman and those associated with them in preparing this work should be well satisfied with their contribution—an invaluable handbook on the fishes of Newfoundland.—E. W. BURRIDGE.